NASA's Earth-Sun System Gateway: an open standards-based portal to geospatial data and services

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***Abstract*—NASA's Earth-Sun System Gateway (ESG) streamlines access to remote geospatial data, imagery, models, and visualizations through open, standard Web protocols. By organizing detailed metadata about online resources into a flexible, searchable registry, it lets scientists, decision-makers, and others access a wide variety of observations and predictions of natural and human phenomena related to Earth Science and the Earth-Sun System, from NASA and other sources.**

We detail ESG's technical design; its use of open-standard interfaces; their potential for Earth-Sun System research and applications; and insights gained from its deployment to date.

***Index Terms*—Distributed information systems, Geographic information systems, Information services, Visualization**

I. Overview

Access to data, observations, and analytical models from diverse sources facilitates interdisciplinary and exploratory research, analysis, and decision-making, particularly in the case of geospatial information [1]. Interoperability (the capacity of independent software components to work together through shared interfaces) greatly facilitates such access. NASA's Earth-Sun system science and applications activities need interoperability among the information and processing components related to spacecraft, airborne, and *in situ* sensors; predictive models; and decision support tools [2].

Open standards for geospatial data access and geoprocessing offer great promise towards meeting NASA's interoperability goals – especially standards promulgated by the Open Geospatial Consortium (OGC) [3], the U.S. National Spatial Data Infrastructure (NSDI) [4], and the ISO Geographic Information / Geomatics committee [5]. But putting geospatial Web services to practical use presents several challenges: finding data and services relevant to a task, visualizing observations and forecasts, and recalling and sharing what one has found. To address these challenges, NASA's Geospatial Interoperability Office (GIO) is adapting and deploying an off-the-shelf geospatial portal product [6], dubbed the Earth-Sun System Gateway (ESG), online at http://esg.gsfc.nasa.gov.

Thanks to extensive use of open standards and interoperability, ESG can draw on a wide variety of online data services, serve a variety of audiences and purposes, adapt to technology or business changes, and function within a larger context of distributed geoprocessing. Applying and adapting ESG's capabilities to the Earth Science / Earth-Sun community is producing several benefits, challenges, and insights.

II. Functions and Components

The Earth-Sun System Gateway (ESG) provides local and distributed search and harvest; visualization of remote data via Web services; publishing of data and services, and user personalization; all linked and enabled by a flexible relational database.

A. Search interface; search service

An ESG session often starts with looking for geospatial data and services based on resource types (various Web services; documents; applications; models; datasets, etc.); topic categories (e.g., agriculture, ecology, oceanography); user-specified keywords; time and date; or geographic location (specified as a place name, or as a point on a map).

Search results consist of "headlines" with the title of the resource and hypertext pointers to additional detail. Search results describing well-known service resources (e.g., instances of the OGC Web Map Service [7] or Z39.50 catalog service [8]) also allow invoking the remote service, using either a built-in ESG client or a separate "helper" application.

As depicted in Fig. 1, ESG also responds to structured queries from external software clients, as part of a larger infrastructure of Web services.

B. Metadata harvest and distributed search

ESG allows searches not only against its own list of resources (data, services, etc.), but against a distributed set of over 200 catalogs known as the National Spatial Data Infrastructure (NSDI) [4] Clearinghouse [9]. ESG harvests the con-

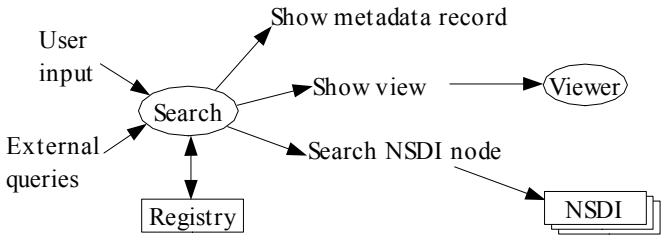

Figure 1. ESG search function

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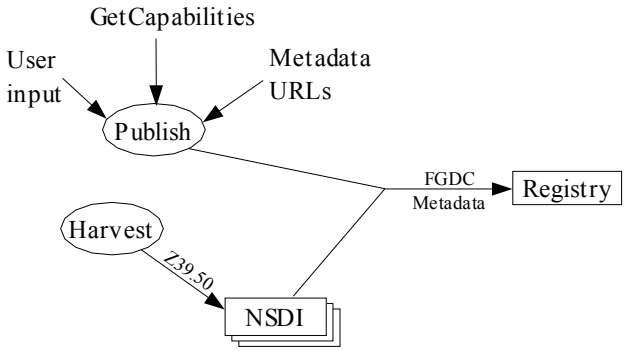

Figure 2. Populating the ESG Registry

tents of these catalogs periodically, and can apply searches to the harvest results, to facilitate discovery of resources from many independent sources across the NSDI. Fig. 2 depicts how ESG's registry is populated through harvest and publishing.

C. Publishing

ESG lets users "publish" (that is, register in its database) a variety of resources, from online Web services to documents, online and offline data, etc. For each resource, the publishing process assembles one or more complete metadata records (see III.A.) from the online service description [for OGC Web services]; from a metadata record referred to by a Uniform Resource Locator (URL); or from user input via a Web-based "wizard." The publishing process restructures each metadata record into a set of harmonized, indexed database objects.

D. Visualization

ESG also includes an interactive viewer that exercises the OGC Web Map Service (WMS) [7] to retrieve visual "layers" from remote servers and to display them in a single view. Fig. 3 depicts the flow of information and control. The viewer provides controls to zoom and pan; manipulate layers; identify data values behind the view; transform the view to a variety of coordinate reference systems; and others.

E. Relational database

Underlying all of ESG's functions is a relational database structured according to the OASIS/ebXML Registry Information Model (ebRIM) [10]. Using the ebRIM constructs, the database records an *extrinsic object* for each identified resource, with indexed *slots* containing searchable elements, *associations* between objects, and *classifications* of objects into categories (types and subtypes) [11]. This flexible structure makes a wide variety of resource types available through a single, common search interface.

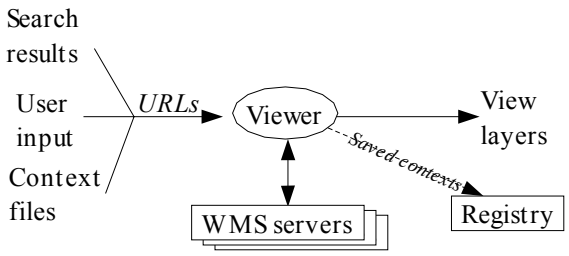

Figure 3. ESG viewer

F. Personalization and collaboration

Finally, ESG offers users several aids to personalization and collaboration. For instance, after retrieving and arranging layers from several servers in ESG's viewer; selecting visual styles for each layer; and zooming into an area of interest, users can save these "map context" details for future reference, or for use by other portal users, as depicted in Fig. 3. A special "Featured Views" page collects all the saved "map contexts" accessible to a user; any one of which may serve as a starting point for further exploration.

Users may also save searches and record a profile of personal contact information. All of these data are saved in the Registry and collected in a "My Gateway" page, for persistence across multiple sessions of using ESG.

III. Standards and Interoperability

All of the ESG portal functions – local search, visualization, distributed search and harvest, publishing, and collaboration – rely on the use of open, well-defined standards, rather than proprietary or ad-hoc data models or interfaces. This enables ESG to draw on a variety of remote data and processing services, and to make its registry of data and services accessible to other software tools.

A. Metadata

Records maintained in ESG's local registry, as well as in its cache harvested from the NSDI Clearinghouse, contain all the elements required by the U.S. FGDC Content Standard for Digital Geospatial Metadata [12] ("FGDC Metadata"). This provides a common basis for decomposing records into the underlying ebRIM structure. ESG's use of the FGDC Metadata standard also allows it to search across the NSDI collection of heterogeneous catalogs.

Furthermore, ESG's publisher interface understands the ISO 19115 standard for metadata [13], so it can populate its own records from hypertext links to ISO 19115-structured metadata. ISO 19115 also provides the basis for the topic categories used in the search and publish interfaces.

B. Web Map Service

ESG's interactive viewer uses the OGC Web Map Service [7] *GetCapabilities* operation to determine service parameters and available data layers; *GetMap* to request visual layers; and *GetFeatureInfo* to inquire about particular locations.

Nearly anything that can be portrayed geospatially can be served up via WMS. Thus, given the right set of WMS servers, ESG is capable of integrating not only static "base map" data, but also real-time and recorded imagery and sensor observations, analytical model results, forecasts, etc., in a common

geospatial visualization environment.

C. Web Map Context documents

ESG lets users save and share "map context" information as files implementing the OGC Web Map Context specification [14]. These files contain the WMS queries that comprise a particular visual composition, with necessary information about layer ordering, styles, and area of interest. By using a open standard structure for these files, ESG's viewer is not limited to using map context files created within its own user interface: it can equally well use ones retrieved from any location on the Web, or uploaded from a user's own computer.

D. Z39.50 and OGC catalog access

ESG's NSDI Clearinghouse queries and harvest rely on the Z39.50 catalog protocol [7], devised by the library community and adapted to FGDC Metadata via the GEO profile [15].

In addition, ESG's external search interface implements the Web profile of the OGC Catalog Interface [16]. This protocol is "stateless" (each request is independent), and thus fits more naturally than Z39.50 into a Web services environment. By implementing the OGC Catalog Interface, ESG is able to serve a diverse and growing set of geospatial catalog clients.

E. Web Feature Service and Feature Portrayal

Finally, ESG implements a portion of the OGC Web Feature Service (WFS) [17]: its "publisher wizard" can retrieve WFS service details through a *GetCapabilities* request and use them to populate searchable records for available feature types; and its viewer allows fetching and portraying data from a WFS server via OGC's Styled Layer Descriptor (SLD) [18].

IV. Applying ESG to NASA science and applications

In summary, ESG employs an integrated mix of standards-based components to help users. But for effective impact, ESG's general-purpose capabilities – publishing, finding, and using geospatial data and services, and collaborating with other users – need to be applied, adapted, and extended to the needs of NASA's Earth-Sun System activities. To this end, the ESG team is engaged in the following activities.

A. Registering files, services, and other resources

For ESG to enhance NASA's applied research and decision support workflows, it must be populated with a variety of specialized, relevant resources – from pointers to working documents and technical reports, to datasets of interest, Web services associated with Earth Science data, models, or sensors, and well-designed "map context" files highlighting phenomena of interest or supporting specific decision processes. Eventually, ESG users will provide most of these; but at the outset the ESG team is "priming the pump" with relevant resources such as descriptions of servers providing imagery, meteorological reports, and agricultural forecasts; context files related to topics of interest; and so on.

B. Quick links to searches and views

As an additional way to meet NASA's specialized needs, ESG includes topical viewpoints into its functions and components – one for each of 12 Applications of National Priority (Agricultural Efficiency, Public health, etc.) and 7 Science Focus Areas (Water & Energy Cycle, Climate Variability, etc.) defined for the Earth-Sun System [19]. Each viewpoint provides "one-click" access to selected ESG keyword searches and context files ("featured views") related to the given topic. Also included are direct hypertext links to online resources pertinent to each topic; this browse capability complements ESG's search capability. These topical views emphasize open standards-based access to data and geoprocessing, so as to foster wider deployment of such services (as described next).

C. Equipping archives and models with standard interfaces

ESG can register any Web-based resource and provide simple (hypertext) access to it. This is useful in itself; but ESG's real *raison d'etre* is invoking Web-based geospatial data services, to integrate their outputs into synthesis views or to retrieve subsets or composites for further analysis. These deeper connections require equipping data archives, models, and other online resources with open, standard Web interfaces (e.g., WMS). The ESG team is working with a few data providers to add WMS interfaces. As more providers support WMS, ESG will be able to draw on those as well.

D. Searching NASA imagery archives

ESG's access to the NSDI Clearinghouse, while interesting, has not yet greatly affected NASA's Earth-Sun System science and applications, as only a few Clearinghouse catalogs describe advanced imagery or other relevant resources. However, this is changing as NASA's GIO collaborates with the Synergy program [20] to equip the Earth Observing System Clearinghouse (ECHO) [21] (a gateway to several large NASA archives) with a Z39.50 interface and to register it with the NSDI Clearinghouse. ECHO connectivity will let ESG harvest and search a broad set of NASA imagery records alongside other Clearinghouse metadata, which will lead to more focused, relevant searches for NASA's science and applications users.

E. Extensions: WCS access and 3-D views

Finally, ESG's functions are being extended to support advanced functions of interest to NASA's Earth-Sun System activities. In particular, NASA's GIO is working with the Synergy program [20] to address scientific data retrieval and rich visualization by equipping ESG with a client for OGC's Web Coverage Service (WCS) [22], and with links to 3-D viewers such as NASA's WorldWind [23]. The WCS client will be especially useful in accessing imagery from NASA's EOSDIS Data Pools [24], which are equipped with a WCS server interface.

V. Conclusions

The ESG experience suggests several insights for designing and deploying distributed, interoperable information systems.

A. Challenges

Developing and deploying ESG has presented a few challenges. Some of these are organizational, rather than technical. For example, not everyone values ESG's discovery capabilities, and its synthesizing view of geospatial information from many sources. These aspects are a boon to open-ended, exploratory work, but may have little impact on more operational, or discipline-specific tasks.

On a more technical note, ESG's reliance on distributed, independently managed services makes it hard to control its performance, or to troubleshoot errors when they occur. This highlights the importance of rigorous error handling in servers and clients, and of supplementing standards with agreed "best practices" to make component behavior more predictable.

ESG has also highlighted the importance of full adherence to standards. Arbitrary shortcuts or simplifying assumptions inevitably lead to errors when drawing on an open ended set of services across different communities of practice, with different priorities and assumptions.

Finally, ESG's graphical user interface is an ongoing subject of discussion and redesign. ESG's many different related capabilities make this design a critical, but difficult, task, requiring interaction with target audiences to understand their usage patterns.

B. Benefits

ESG's first-order benefit is to provide a solution to several growing problems intrinsic to Web-mediated work: finding distributed services relevant to a task, invoking them to obtain useful results, and [for service providers] publishing service details "once and for all" for a broad audience.

By putting a broad set of open standards into practice, ESG also serves as a showcase illustrating what can be done with interoperable components. It also serves as a reference implementation for developers of servers and clients to test against.

By encouraging providers of data, metadata, and services to use open standards, ESG contributes to a robust and flexible information infrastructure; extensible to incorporate new technology components or business relationships.

Finally, ESG facilitates the discovery of new information from many different sources. This fosters interdisciplinary, exploratory, and collaborative work, which is a precursor to innovative research, applications, and decisions.

References

[1] Chorley, Roger, "Some reflections on the handling of geographic information," International Journal of Geographic Information Systems, Vol. 2, No. 1, 1988, pp. 3-9.

[2] Ronald J. Birk, "Extending NASA Earth-Sun System research results to serve GEOSS societal benefits," Third International Workshop on the Analysis of Multitemporal Remote Sensing Images, May 2005, in press.

[3] Open Geospatial Consortium (OGC); http://www.opengeospatial.org

[4] Executive Office of the President (EOP). "Coordinating geographic data acquisition and access: the National Spatial Data Infrastructure" (Presidential Executive Order No. 12906), Federal Register, Vol. 59, No. 71, 1994, pp. 17671-17674; http://www.fgdc.gov/publications/documents/geninfo/execord.html

[5] ISO/TC 211: Geographic Information / Geomatics; http://www.isotc211.org

[6] Compusult Ltd., "Data Management and GIS Solutions: Web Enterprise Suite"; http://www.compusult.net/cslt_prod_dm.html

[7] OGC Web Map Service, Open Geospatial Consortium, 2004; http://portal.opengis.org/files/?artifact_id=5316

[8] ANSI/NISO Z39.50-2003 Information Retrieval: Application Service Definition & Protocol Specification, National Information Standards Org., 2003; http://www.niso.org/standards/resources/Z39-50-2003.pdf

[9] Federal Geographic Data Committee, "FGDC Geospatial Data Clearinghouse Activity"; http://www.fgdc.gov/clearinghouse/clearinghouse.html

[10] OASIS/ebXML Registry Information Model (ebRIM) v2.0, Organization for the Advancement of Structured Information Standards (OASIS), April 2002; http://www.oasis-open.org/committees/regrep/documents/2.0/specs/ebrim.pdf

[11] Vretanos, Panagiotis, "Mapping WMS and WFS Capabilities Documents into the OGC Registry Information Model," Document 03-041, Open Geospatial Consortium (unpublished), 2003; http://portal.opengeospatial.org/files/?artifact_id=1299

[12] Content Standard for Digital Geospatial Metadata, Version 2, Federal Geographic Data Committee, 1998; http://www.fgdc.gov/metadata/contstan.html

[13] Geographic Information – Metadata, ISO Technical Committee 211, 2003, pp. 102-103; http://www.ncits.org/ref-docs/FDIS_19115.pdf

[14] OGC Web Map Context Documents, Open Geospatial Consortium, 2003; http://portal.opengeospatial.org/files/?artifact_id=3841

[15] Douglas Nebert, Z39.50 Application Profile for Geospatial Metadata or "GEO" – Version 2.2, 2000; http://www.blueangeltech.com/Standards/GeoProfile/geo22.htm

[16] OGC Catalog Interface, Open Geospatial Consortium, 2004; http://portal.opengis.org/files/?artifact_id=5929

[17] OGC Web Feature Service, Open Geospatial Consortium, 2002; http://portal.opengeospatial.org/files/?artifact_id=7176

[18] OGC Styled Layer Descriptor, Open Geospatial Consortium, 2002; http://portal.opengeospatial.org/files/?artifact_id=3837

[19] NASA, Earth Science Applications Plan, Office of Earth Science, NP 2004 08 368 HQ, July 2004, 104pp.; http://science.hq.nasa.gov/strategy/AppPlan.pdf

[20] Kalluri, Satya, and Peter Gilruth, "Moving from research to applications: NASA's EOS data for decision makers," American Meteorological Society 84th Annual meeting, January 2004; http://ams.confex.com/ams/84Annual/techprogram/paper_74641.htm

[21] Earth Observing System Clearinghouse (ECHO), Overview; http://www.echo.eos.nasa.gov/overview/

[22] OGC Web Coverage Service, Open Geospatial Consortium, 2003, http://portal.opengeospatial.org/files/?artifact_id=3837&version=2

[23] NASA WorldWind, March 2005; http://worldwind.arc.nasa.gov/index.html

[24] Marley, Steve, Mike Moore, and Bruce Clark, "Building Cost-Effective Remote Data Storage Capabilities for NASA's EOSDIS," Twentieth IEEE/Eleventh NASA Goddard Conference on Mass Storage Systems & Technologies, 2003; http://storageconference.org/2003/papers/04-Marley-Building%20.pdf